REFERENCE APPENDICES

CALIFORNIA ENERGY COMMISSION

REGULATIONS / STANDARDS

for the 2008 BUILDING ENERGY EFFICIENCY STANDARDS

FOR RESIDENTIAL AND NONRESIDENTIAL BUILDINGS

JOINT APPENDICES

RESIDENTIAL APPENDICES

NONRESIDENTIAL APPENDICES

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Residential Appendix RA3

Appendix RA3 – Residential Field Verification and Diagnostic Test Protocols

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RA3.1 Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems

RA3.1.1 Purpose and Scope

RA3.1 contains procedures for measuring the air leakage in forced air distribution systems as well as procedures for verifying duct location, surface area and R-value.

RA3.1 applies to air distribution systems in both new and existing low-rise residential buildings.

RA3.1 provides required procedures for installers, HERS raters and others who need to perform field verification of the efficiency of air distribution systems. Algorithms for determining distribution system efficiency are contained in Chapter 3 of the residential ACM Manual. Table RA3.1-1 is a summary of the tests and criteria included in RA3.1.

Table RA3.1-1 – Summary of Diagnostic Measurements

Diagnostic	Description	Procedure
Supply Duct Location, Surface Area and R-value	Verify that duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value, and installation of buried ducts.	RA3.1.4.1 Diagnostic Supply Duct Location, Surface Area and R-value RA3.1.4.1.1.1 Verified Duct Design
Duct Leakage	Verify that duct leakage is less than the criteria or in the case of existing ducts that all accessible leaks have been sealed.	Diagnostic Duct Leakage

RA3.1.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RA3.1.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of plus or minus 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes, Dwyer A303 or equivalent.

RA3.1.2.2 Duct Leakage Measurements

Duct leakage airflows during duct leakage testing shall be measured with digital gauges that have an accuracy of plus or minus 3 percent or better.

RA3.1.2.3 Calibration

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the accuracy requirement specified in Section RA3.1.2. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

RA3.1.3 Apparatus

RA3.1.3.1 Duct Pressurization

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section RA3.1.2.

RA3.1.3.2 Duct Leakage to Outside (Existing Duct Systems)

The apparatus for measuring duct leakage to outside shall include a fan that is capable of maintaining the pressure within the conditioned spaces in the house at 25 Pa relative to the outdoors. The fan most commonly used for this purpose is known as a "blower door" and is typically installed within a temporary seal of an open exterior doorway.

RA3.1.3.3 Smoke-Test of Accessible-Duct Sealing (Existing Duct Systems)

The apparatus for determining leakage in and verifying sealing of all accessible ducts shall also include means for introducing controllable amounts of non-toxic visual smoke into the duct pressurization apparatus for identifying leaks in accessible portions of the duct system. Adequate smoke shall be used to assure that any accessible leaks will emit visibly identifiable smoke.

RA3.1.4 Procedures

This section describes the procedures used to verify diagnostic inputs for the calculation of improved duct efficiency.

RA3.1.4.1 Diagnostic Supply Duct Location, Surface Area and R-value

The performance calculations in the Residential ACM Manual, Section 3.12.3, allow credit for duct systems that are designed to be in advantageous locations that have reduced supply duct surface areas and/or that provide higher R-values for portions of the system. Compliance credit may be taken for one or more of these duct system improvements in any combination. The procedure in this section is used to verify that the duct system is installed according to the design and meets the requirements for compliance credit.

RA3.1.4.1.1 Duct System Design Requirements

The design shall show the location of equipment and all supply and return registers. The size, R-value, and location of each duct segment shall be shown in the design drawing, which shall be cross referenced to the supply duct details report in the Certificate of Compliance. For ducts buried in attic insulation, the portion in contact with the ceiling or deeply buried shall be shown and the design shall include provisions for ducts crossing each other, interacting with the structure, and changing vertical location to connect with elevated equipment or registers as required. Credit shall be allowed for buried ducts only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above.

RA3.1.4.1.1.1 Verified Duct Design

The system meets the Verified Duct Design criteria if it is verified to be consistent with a documented duct design that meets the requirements of this section. The duct system shall be designed to meet the required system airflow rate with the manufacturer specified available external static pressure for the specified system air handler at that airflow. The duct design shall have calculations showing the duct system will operate at equal to or greater than 0.0292 cfm/Btu (350 cfm/12000 Btu) in cooling speed (350 cfm per nominal ton of cooling capacity specified by the manufacturer) or, if heating only, equal to or greater than 16.8 cfm per 1000 Btu/hr furnace nominal output specified by the manufacturer. The duct design shall be based on an industry standard design methodology such as ACCA Manual D or equivalent, and shall take into account: the available external static pressure from the air handler, the pressure drop of external devices, the equivalent length of the duct runs, as well as the size, type and configuration of the ducts and fittings. The duct design specifications and layout shall be included with the building plans submitted to the enforcement agency, and a copy of the duct design layout shall be posted or made available with the building permit(s) issued for the building, and

shall be made available to the enforcement agency, installing contractor, and HERS rater for use during the installation work and for all applicable inspections.

RA3.1.4.1.2 Verifying the Duct System Installation

The location of all supply and return registers shall be verified from an inspection of the interior of the dwelling unit. The location of the equipment and the size, R-value, and location of each duct segment shall be verified by observation in the spaces where they are located. Deviations from the design shall not be allowed.

RA3.1.4.1.3 Verification for Ducts to be buried in Attic Insulation

This procedure and the procedure of RA3.1.4.2 shall be carried out prior to covering the ducts with insulation. Ducts to be buried shall be insulated to R4.2 or greater. In addition ducts designed to be in contact with the ceiling shall be in continuous contact with the ceiling drywall or ceiling structure not more than 3.5 inches from the ceiling drywall. A sign must be hung near the attic access reading "Caution: Buried Ducts. Markers indicate location of buried ducts." All ducts which will be completely buried shall have vertical markers which will be visible after insulation installation at not more than every 8 feet of duct length and at the beginning and end of each duct run.

RA3.1.4.2 System Fan Flow

For the purpose of establishing duct leakage criteria, the system fan flow shall be calculated using RA3.1.4.2.1, RA3.1.4.2.2, or RA3.1.4.2.3.

RA3.1.4.2.1 Default System Fan Flow

Default system fan flow may be used only for homes where the duct system is being tested before the air conditioning and heating system is installed and the equipment specification is not known. For heating only systems the default fan flow shall be 0.5 CFM per ft^2 of Conditioned Floor Area.

RA3.1.4.2.2 Nominal System Fan Flow

For heating only systems the fan flow shall be 21.7 CFM x Heating Capacity in thousands of Btu/hr. For systems with cooling, the fan flow shall be 400 CFM per nominal ton of cooling capacity as specified by the manufacturer or the heating only value, whichever is greater.

RA3.1.4.2.3 Measured System Fan Flow

The fan flow shall be as measured according to a procedure in Section RA3.3.3

RA3.1.4.3 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used by installers and raters to verify that total leakage meets the criteria for any sealed duct system specified in the compliance documents. Diagnostic Duct Leakage from Fan Pressurization of Ducts (Section RA3.1.4.3.1) is the only procedure that may be used by a HERS rater to verify duct sealing in a new home. Table RA3.1-2 shows the leakage criteria and test procedures that may be used to demonstrate compliance.

Table RA3.1-2 Duct Leakage Tests

Case	User and Application	Leakage criteria, % of total fan flow	Procedure
Sealed and tested new duct systems	Installer Testing at Final HERS Rater Testing	6%	RA3.1.4.3.1
	Installer Testing at Rough- in, Air Handling Unit Installed	6% Installer Inspection at Final	RA3.1.4.3.2 RA3.1.4.3.2.1
	Installer Testing at Rough-in, Air Handling Unit Not Installed	4% Installer Inspection at Final	RA3.1.4.3.2 RA3.1.4.3.2.2
Ducts in conditioned space	Installer Testing HERS Rater Testing	25 CFM Leakage to Outside	RA3.1.4.3.9
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15% Total Duct Leakage	RA3.1.4.3.1
	Installer Testing HERS Rater Testing	10% Leakage to Outside	RA3.1.4.3.4
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Inspection and Smoke Test	RA3.1.4.3.5 RA3.1.4.3.6, RA3.1.4.3.7
	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed Inspection and Smoke Test with 100% Verification	RA3.1.4.3. 6 RA3.1.4.3. 7, RA3.1.4.3. 8

RA3.1.4.3.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or a rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing the entire duct system to plus 25 Pa with respect to outside. The following procedure shall be used for the fan pressurization tests:

1. Verify that the air handler, supply and return plenums and all the connectors, transition pieces, duct boots and registers are installed. The entire duct system shall be included in the total leakage test.
2. For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used and if a platform or other building cavity used to house the air distribution system has been newly installed or altered, it contains a duct or is ducted with duct board or sheet metal.
3. Seal all the supply and return registers except for one return register or the system fan access.
4. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
5. Install a static pressure probe at a supply register or the supply plenum.
6. Adjust the fan flowmeter to produce a plus 25 Pa(0.1 inches water) pressure at the supply register or the supply plenum with respect to the outside or with respect to the building space with the entry door open to the outside.
7. Record the flow through the flowmeter; this is the leakage flow at 25 Pa.
8. Divide the leakage flow by the total fan flow determined by the procedure in Section RA3.1.4.2 and convert to a percentage. If the leakage flows percentage is less than the criteria from Table RA3.1-2 the system passes.

RA3.1.4.3.2 Diagnostic Duct Leakage at Rough-in Construction Stage

Installers may determine duct leakage in new construction by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing. When using this measurement technique, the installer shall complete additional inspection (as described in section RA3.1.4.3.2.3) of duct integrity after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.

The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The following procedure (either RA3.1.4.3.2.1 or RA3.1.4.3.2.2) shall be used:

RA3.1.4.3.2.1 Ducts with the Air Handling Unit Installed and Connected:

For total leakage:

1. Verify that supply and return plenums and all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used to house the air distribution system, it shall contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.
2. Seal all the supply duct boots and return boxes except for one return duct box.
3. Attach the fan flowmeter device at the unsealed duct box.
4. Insert a static pressure probe at one of the sealed supply duct boots.
5. Adjust the fan flowmeter to maintain a plus 25 Pa (0.1 inches water) pressure in the duct system with respect to the outside or with respect to the building space with the entry door open to the outside.
6. Record the flow through the flowmeter; this is the leakage flow at 25 Pa.
7. Divide the leakage flow by the total fan flow determined by the procedure in Section RA3.1.4.2 and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RA3.1-2 the system passes.

RA3.1.4.3.2.2 Ducts with Air Handling Unit Not Yet Installed:

For total leakage:

1. Verify that all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used to house the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.
2. Use a duct connector to connect the supply and/or return duct box to the fan flowmeter. Supply and return leaks may be tested separately.
3. Seal all the supply duct boots and/or return boxes except for one supply or return duct box.
4. Attach the fan flowmeter device at the unsealed duct box.
5. Insert a static pressure probe at one of the sealed supply duct boots.
6. Adjust the fan flowmeter to produce a plus 25 Pa (0.1 inches water) pressure at the supply plenum with respect to the outside or with respect to the building space with the entry door open to the outside.
7. Record the flow through the flowmeter; this is the leakage flow at 25 Pa.
8. If the supply and return ducts are tested separately, repeat items 4 through 6 with the flow meter attached to the unsealed return box and the static pressure probe in the return plenum, then add the two leakage rates together to get a total leakage flow.
9. Divide the leakage flow by the total fan flow determined by the procedure in Section RA3.1.4.2 and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RA3.1-2 the system passes.

RA3.1.4.3.3 Installer Visual Inspection at Final Construction Stage

After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, the following procedure shall be used:

1. Remove at least one supply and one return register, and verify that the spaces between the register boot and the interior finishing wall are properly sealed.

2. If the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed.
3. Inspect all joints to ensure that no cloth backed rubber adhesive duct tape is used.

RA3.1.4.3.4 Duct Leakage to Outside from Fan Pressurization of Ducts

The objective of this test is to determine the duct leakage to outside. This measurement is used to verify that duct systems are entirely located within conditioned space. The procedure is also used to provide an alternate leakage measurement where it is likely that some of the total duct leakage is to within the conditioned space. The duct leakage to outside shall be determined by pressurizing the ducts and the conditioned space of the house to 25 Pa with respect to outside. The following procedure shall be used for the fan pressurization test of leakage to outside:

1. Seal all the supply and return registers except one return register or the fan access door.
2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
3. Install a static pressure probe at the supply plenum.
4. Attach a blower door to an external doorway.
5. If any ducts are located in an unconditioned basement, all doors or accesses between the conditioned space and the basement shall be closed, and at least one operable door or window (if it exists) between the basement and outside shall be open during the test.
6. If the ducts are located in a conditioned basement, any door between the basement and the remaining conditioned space shall be open, and any basement doors or windows to outside must be closed during the test.
7. Adjust the blower door fan to provide plus 25 Pa (0.1 inches of water) pressure in the conditioned space with respect to outside.
8. Adjust the fan/flowmeter to maintain zero pressure (plus or minus 0.5Pa) between the ducts and the conditioned space, and adjust the blower door fan to maintain plus 25 Pa (0.1 inches of water) pressure in the conditioned space with respect to outside. This step may require several iterations.
9. Record the flow through the flowmeter (Q_{25}; this is the duct leakage at 25 Pa. To verify ducts in conditioned space compare this flow to the criterion
10. Where the criterion is a percentage of total flow, divide the leakage flow by the total fan flow determined by the procedure in Section RA3.1.4.2 and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RA3.1-2 the system passes.

RA3.1.4.3.5 Leakage Reduction from Fan Pressurization of Ducts

For altered existing duct systems that do not pass the Total Leakage (RA3.1.4.3.1) or Leakage to Outside (RA3.1.4.3.4) tests, the objective of this test is to show that the original leakage is reduced through duct sealing as specified in Table RA3.1-2. The following procedure shall be used:

1. Use the procedure in RA3.1.4.3.1 to measure the leakage before commencing duct sealing.
2. After sealing is complete use the same procedure to measure the leakage after duct sealing.
3. Subtract the sealed leakage from the original leakage and divide the remainder by the original leakage. If the leakage reduction is 60 percent or greater of the original leakage, the system passes.
4. Complete the Smoke Test specified in RA3.1.4.3.7.
5. Complete the Visual Inspection specified in RA3.1.4.3.8.

RA3.1.4.3.6 Sealing of All Accessible Leaks

For altered existing duct systems that do not pass any of the Total Leakage (RA3.1.4.3.1), Leakage to Outside (RA3.1.4.3.3) or Leakage Improvement (RA3.1.4.3.4) tests, the objective of this test is to show that all accessible leaks are sealed. The following procedure shall be used:

1. At a minimum, complete the procedure in RA3.1.4.3.1 to measure the leakage before commencing duct sealing.
2. Seal all accessible ducts.
3. After sealing is complete use the same procedure to measure the leakage after duct sealing.
4. Complete the Smoke Test as specified in RA3.1.4.3.7.
5. Complete the Visual Inspection as specified in RA3.1.4.3.8.
6. Install the required label on the system stating that the system fails the leakage tests.

RA3.1.4.3.7 Smoke-Test of Accessible-Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 Pa relative to the duct surroundings, with all grilles and registers in the duct system sealed.
2. Visually inspect all accessible portions of the duct system during smoke injection.
3. The system shall pass the test if one of the following conditions is met:
    i. No visible smoke exits the accessible portions of the duct system.
    ii. Smoke only emanates from the furnace cabinet which is gasketed and sealed by the manufacturer and no visible smoke exits from the accessible portions of the duct system.

RA3.1.4.3.8 Visual Inspection of Accessible Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of this inspection in conjunction with the smoke test (RA3.1.4.3.7) is to confirm that all accessible leaks have been sealed. Visually inspect to verify that the following locations have been sealed:

1. Connections to plenums and other connections to the forced air unit
2. Refrigerant line and other penetrations into the forced air unit
3. Air handler door panel (do not use permanent sealing material, metal tape is acceptable)
4. Register boots sealed to surrounding material
5. Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.

RA3.1.4.3.9 Verified Low Leakage Ducts in Conditioned Space

When ducts are located in conditioned space, additional credit is available for Low Leakage Ducts, if duct leakage to outside equal to or less than 25 cfm when measured in accordance with Section RA3.1.4.3.4. The home must also be qualified to receive the credit for verified ducts in conditioned space. The ACM credit for Low Leakage Ducts in Conditioned Space is shown on Table R3-34 of the Residential ACM.

RA3.1.4.3.10 Verified Low Leakage Air Handler with Sealed and Tested Duct System

An additional credit is available for verified low leakage ducts if a Low Leakage Air Handler is installed The low leakage air handler cabinet (furnace or heat pump fan and inside coil) must be certified to the Commission to leak 2 percent or less of its nominal air conditioning cfm delivered when pressurized to 1-inch water gauge with all present air inlets, air outlets, and condensate drain port(s) sealed. The air handler must be connected to a Sealed and Tested New Duct System to receive the credit.

The ACM allows the duct efficiency calculation to use the actual measured duct leakage if it is equal to or less than 6 percent of airflow.

RA3.2 Procedures for Determining Refrigerant Charge for Split System Space Cooling Systems Without a Charge Indicator Display

RA3.2.1 Purpose and Scope

The purpose of this procedure is to determine and verify that residential split system space cooling systems and heat pumps have the required refrigerant charge and that the metering device is working as designed. The procedures only apply to ducted split system central air conditioners and ducted split system central heat pumps. The procedures do not apply to packaged systems. For dwelling units with multiple split systems or heat pumps, the procedure shall be applied to each system separately. The procedures detailed in Section RA3.2 are to be used after the HVAC installer has installed and charged the air conditioner or heat pump system in accordance with the manufacturer's instructions and specifications. The installer shall certify to the builder, building official and HERS rater that he/she has followed the manufacturer's instructions and specifications prior to proceeding with the procedures in this appendix.

Appendix RA3.2 defines two procedures, the Standard Charge Measurement Procedure in Section RA3.2.2 and the Alternate Charge Measurement Procedure in Section RA3.2.3. The standard procedure shall be used when the outdoor air temperature is 55°F or above and shall always be used for HERS rater verification. HVAC installers who must complete system installation when the outdoor temperature is below 55°F shall use the alternate procedure.

The following sections document the instrumentation needed, the required instrumentation calibration, the measurement procedure, and the calculations required for each procedure.

The reference method algorithms adjust (improve) the efficiency of split system air conditioners and heat pumps when they are diagnostically tested to have the correct refrigerant charge and the metering device is operating properly. Table RA3.2-1 summarizes the algorithms that are affected by refrigerant charge testing.

Table RA3.2-1 – Summary of Diagnostic Measurements

Input to the Algorithms	Description	Standard Design Value	Proposed Design	
			Default Value	Procedure
Cooling System Refrigerant Charge and Metering	F_{CID} takes on a value of 0.96 when the system has been diagnostically tested for the correct refrigerant charge, or a charge Indicator Display is field verified. Otherwise, F_{CID} has a value of 0.90.	Split systems are assumed to have refrigerant charge testing or a Charge Indicator Display when required by Package D.	No refrigerant charge testing or Charge Indicator Display.	RA3.2.2 or RA3.2.3

Note that diagnostically testing the refrigerant charge requires a minimum level of airflow across the evaporator coil, as defined in RA3.2.2.7.

RA3.2.2 Standard Charge Measurement Procedure

This section specifies the Standard charge measurement procedure. Under this procedure, required refrigerant charge is calculated using the Superheat Charging Method for Fixed Metering Devices and the Subcooling Charging Method for Thermostatic Expansion Valves (TXV) and Electronic Expansion Valves (EXV). The method also checks airflow across the evaporator coil to determine whether the charge test is valid using the Temperature Split Method. The measurement methods in RA3.3 may be substituted for the Temperature Split Method; however the Temperature Split Method may not be substituted for the measurement methods in RA3.3.

The standard procedure detailed in this section shall be completed when the outdoor temperature is 55°F or higher after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. If the outdoor temperature is between 55°F and 65°F the return dry bulb temperature shall be maintained above 70°F during the test. All HERS rater verifications are required to use this standard procedure.

RA3.2.2.1 Minimum Qualifications for this Procedure

Persons carrying out this procedure shall be qualified to perform the following:

1. Obtain accurate pressure/temperature readings from refrigeration gauges.
2. Obtain accurate temperature readings from electronic thermometer and temperature sensors.
3. Check calibration of refrigerant gauges using a known reference pressure
4. Check calibration of electronic thermometer and temperature sensors using a known reference temperature.
5. Check calibration of electronic temperature thermometer and pipe temperature sensors using a pipe at a known reference temperature in a surrounding atmosphere at least 40ºF different from the pipe temperature.
6. Determine best location for temperature measurements in duct system and on refrigerant lines.
7. Calculate the measured superheat and temperature split.
8. Determine the required superheat and temperature split, based on the conditions present at the time of the test.
9. Determine if measured values are reasonable.

RA3.2.2.2 Instrumentation Specifications

Instrumentation for the procedures described in this section shall conform to the following specifications:

RA3.2.2.2.1 Digital Thermometer

Digital thermometer shall have dual channel capability in Celsius or Fahrenheit readout with:

1. Accuracy: ± (0.1% of reading + 1.3º F).
2. Resolution: 0.2º F.

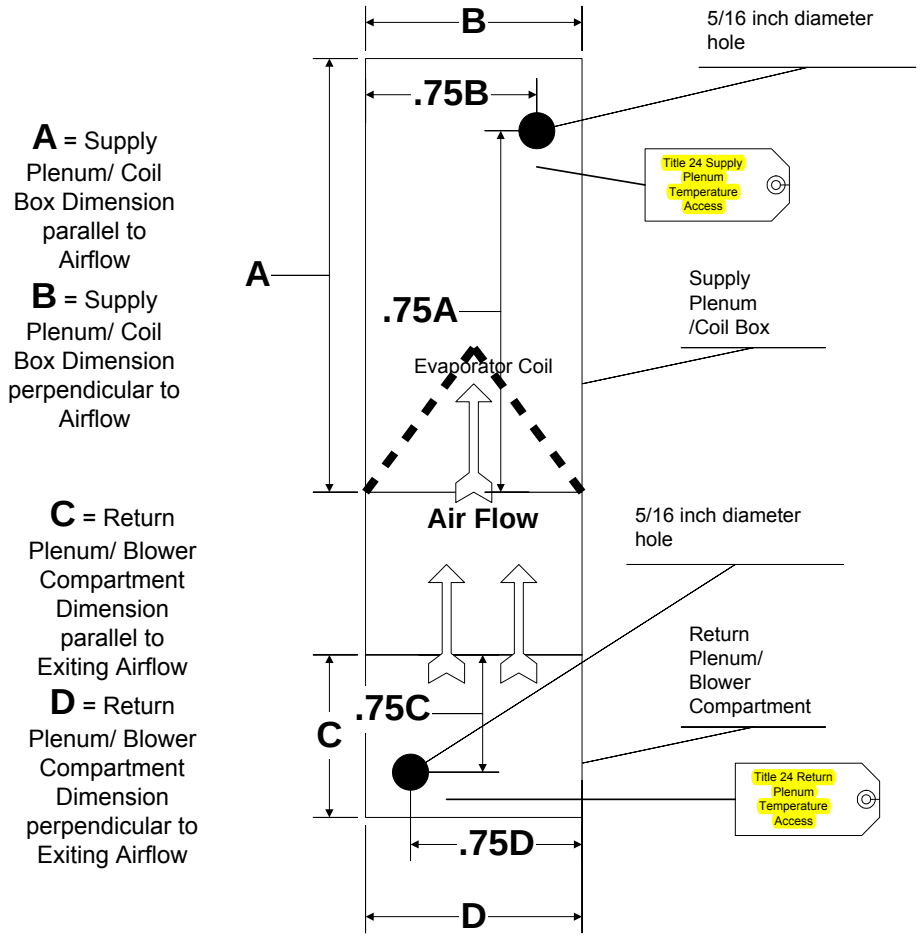
RA3.2.2.2.2 Temperature Sensors and Temperature Measurement Access Holes (TMAH)

Measurements require four (4) temperature sensors with a response time that produces the accuracy specified in Section RA3.2.2.2.1 within 15 seconds of immersion in a bath at least 40º F different from the surrounding conditions.

Measurements require one (1) cotton wick for measuring wet-bulb temperatures.

Measurements require at two (2) pipe temperature sensors that produce the accuracy specified in Section RA3.2.2.2.1 within 15 seconds of being applied to a pipe at least 40º F different from the surrounding conditions.

There shall be two labeled temperature measurement access holes, one in the supply plenum and one in the return plenum. The temperature measurements shall be taken at the following locations:


A = Supply Plenum/ Coil Box Dimension parallel to Airflow
B = Supply Plenum/ Coil Box Dimension perpendicular to Airflow
C = Return Plenum/ Blower Compartment Dimension parallel to Exiting Airflow
D = Return Plenum/ Blower Compartment Dimension perpendicular to Exiting Airflow
B
.75B
A
.75A
C
.75C
.75D
D
5/16 inch diameter hole
Title 24 Supply Plenum Temperature Access
Supply Plenum /Coil Box
Evaporator Coil
Air Flow
5/16 inch diameter hole
Return Plenum/ Blower Compartment
Title 24 Return Plenum Temperature Access

Each location shall have a 5/16" (8 mm) diameter hole. The supply location shall be labeled "Title 24 – Supply Temperature Access" in at least 12-point type. The return location shall be labeled "Title 24 – Return Temperature Access" in at least 12-point type. These locations can be in any one of the four sides of the plenums.

RA3.2.2.3 Refrigerant Gauges and Saturation Temperature Measurement Sensors (STMS)

A refrigerant gauge with an accuracy of plus or minus 3 percent shall be used. As an alternative, two saturation temperature measurement sensors (sensors) shall be placed in a manner and location determined by the equipment manufacturer as measuring the saturation temperature of the refrigerant in the evaporator coil and in the condenser coil within 1.3 ºF. These sensors shall be permanently mounted and have standard temperature sensor mini plugs accessible to the installing technician and the HERS rater without changing the airflow through the condenser coil. Other saturation temperature measurement sensor instrumentation methodologies shall be allowed if the specifications for the methodologies are approved by the Executive Director.

RA3.2.2.4 Calibration

The accuracy of instrumentation shall be maintained using the following procedures. A sticker with the calibration check date shall be affixed to each instrument calibrated.

RA3.2.2.4.1 Thermometer/ and Temperature Sensor Field Calibration Procedure

Thermometers/temperature sensors shall be calibrated monthly to ensure that they are reading accurate temperatures.

The following procedure shall be used to check thermometer/temperature sensor calibration:

1. Fill an insulated cup (foam) with crushed ice. The ice shall completely fill the cup. Add water to fill the cup.
2. Insert two sensors into the center of the ice bath and attach them to the digital thermometer.
3. Let the temperatures stabilize. The temperatures shall be 32°F (plus or minus 1°F). If the temperature is off by more than 1°F make corrections according to the manufacturer's instructions. Any sensors that are off by more than 2°F shall be replaced.
4. Switch the sensors and ensure that the temperatures read on both channels are still within plus or minus 1°F of 32°F.
5. Affix sticker with calibration check date onto sensor.
6. Repeat the process for all sensors.

RA3.2.2.4.2 Refrigerant Gauge Field Check Procedure

Refrigerant gauges shall be checked monthly to ensure that the gauges are reading the correct pressures and corresponding temperatures. The following procedure shall be used to check gauge calibration:

1. Place a refrigerant cylinder in a stable environment and let it sit for 4 hours minimum to stabilize to the ambient conditions.
2. Attach a calibrated sensor to the refrigerant cylinder using tape so that there is good contact between the cylinder and the sensor.
3. Insulate over the sensor connection to the cylinder.
4. Zero the low side and high side refrigerant gauges with all ports open to atmospheric pressure (no hoses attached).
5. Re-install the hose, attach the high side gauge to the refrigerant cylinder, and open the valves to measure the pressure in the refrigerant cylinder.
6. Read the temperature of the sensor on the refrigerant cylinder.
7. Using a pressure/temperature chart for the refrigerant, look up the pressure that corresponds to the temperature measured.
8. If gauge does not read the correct pressure corresponding to the temperature, the gauge is out of calibration and needs to be replaced or returned to the manufacturer for calibration.
9. Close the valve to the refrigerant cylinder, and bleed off a small amount of refrigerant to lower the high side pressure to give a corresponding temperature to between 45°F and 55°F.
10. Open the valves between the high side gauge and low side gauge.
11. If the two gauges corresponding refrigerant temperatures do not read within 1°F of each other, the low side gauge is out of calibration and needs to be replaced or returned to the manufacturer for calibration
12. Affix sticker with calibration check date onto refrigerant gauge.

RA3.2.2.5 Charge Measurement

The following procedure shall be used to obtain measurements necessary to adjust required refrigerant charge as described in the following sections:

1. If the condenser air entering temperature is less than 65ºF, establish a return air dry bulb temperature sufficiently high that the return air dry bulb temperature will be not less than 70ºF prior to the measurements at the end of the 15-minute period in step 2.
2. Connect the refrigerant gauges to the service ports, taking normal precautions to not introduce air into the system.

3. Turn the cooling system on and let it run for 15 minutes to stabilize temperatures and pressures before taking any measurements. While the system is stabilizing, proceed with setting up the temperature sensors.
4. Attach one pipe temperature sensor to the suction line near the suction line service valve and attach one pipe temperature sensor to the liquid line near the liquid line service valve.
5. Attach a temperature sensor to measure the condenser entering air dry-bulb temperature. The sensor shall be placed so that it records the average condenser air entering temperature and is shaded from direct sun.
6. Be sure that all cabinet panels that affect airflow are in place before making measurements. The temperature sensors shall remain attached to the system until the final charge is determined.
8. Place wet-bulb temperature sensor (cotton wick) in water to ensure it is saturated when needed. Do not get the dry-bulb temperature sensors wet.
9. Insert the dry-bulb temperature sensor in the supply plenum at the "Title 24 – Supply Temperature Access" detailed in Section RA3.2.2.2.2.
10. At 12 minutes, insert a dry-bulb temperature sensor and a wet-bulb temperature sensor into the return plenum at the "Title 24 – Return Temperature Access" detailed in Section RA3.2.2.2.2.
11. At 15 minutes when the return plenum wet-bulb temperature has stabilized, using the temperature sensors already in place, measure and record the return (evaporator entering) air dry-bulb temperature ($T_{return, db}$) and the return (evaporator entering) air wet-bulb temperature ($T_{return, wb}$).
12. Using the dry-bulb temperature sensor already in place, measure and record the supply (evaporator leaving) air drybulb temperature ($T_{supply, db}$).
13. Using the refrigerant gauge or saturation temperature measurement sensor already attached, measure and record the evaporator saturation temperature ($T_{evaporator, sat}$) from the low side gauge.
14. Using the refrigerant gauge or saturation temperature measurement sensor already attached, measure and record the condenser saturation temperature ($T_{eondenser, sat}$) from the high side gauge.
15. Using the pipe temperature sensor already in place, measure and record the suction line temperature ($T_{suction,}$).
16. Using the pipe temperature sensor already in place, measure and record the liquid line temperature (T_{liquid}).
17. Using the dry-bulb temperature sensor already in place, measure and record the condenser (entering) air dry-bulb temperature ($T_{condenser, db}$).

The above measurements shall be used to adjust refrigerant charge and airflow as described in following sections.

RA3.2.2.6 Refrigerant Charge and Metering Device Calculations

The following steps describe the calculations to determine if the system meets the required refrigerant charge and metering device function using the measurements described in Section RA3.2.2.5. If a system fails, then remedial actions must be taken. If the refrigerant charge is changed and the airflow is being tested with the *Temperature Split Method*, then the airflow shall be re-tested. Be sure to run the air conditioner for 15 minutes after the final adjustments before taking any measurements. Both the airflow and charge must be re-tested until they simultaneously pass.

RA3.2.2.6.1 Fixed Metering Device Calculations

The Superheat Charging Method is used only for systems equipped with fixed metering devices. These include capillary tubes and piston-type metering devices.

1. Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature.

Actual Superheat = $T_{suction,} - T_{evaporator, sat}$.

2. Determine the Target Superheat using Table RA3.2-2 using the return air wet-bulb temperature ($T_{return, wb}$) and condenser air dry-bulb temperature ($T_{condenser, db}$).

3. If a dash mark is read from Table RA3.2-2, the target superheat is less than 5°F. Note that **a valid refrigerant charge verification test cannot be performed under these conditions**. The usual reason for a target superheat determination of less than 5°F is that outdoor conditions are too hot and dry. One of the following is needed so a target superheat value can be obtained from Table RA3.2-2 either 1) turn on the space heating system and/or open the windows to warm up indoor temperature; or 2) retest at another time when conditions are different. Repeat the measurement procedure as necessary to establish the target superheat. Allow system to stabilize for 15 minutes before the final measurements are taken.

4. Calculate the difference between actual superheat and target superheat (Actual Superheat - Target Superheat).

5. In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer and the HERS Rater.

   For the Installer, if the difference is between minus 5°F and plus 5°F, then the system **passes** the required refrigerant charge criterion.

   For the HERS Rater inspecting the system, if the difference is between minus 6°F and plus 6°F, then the system **passes** the required refrigerant charge criterion.

6. For the Installer, if the difference is greater than plus 5°F, then the system **does not pass** the required refrigerant charge criterion and the Installer shall add refrigerant. Adjust refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.

7. For the Installer, if the difference is between minus 5°F and minus100°F, then the system **does not pass** the required refrigerant charge criterion, the Installer shall remove refrigerant. Adjust refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.

RA3.2.2.6.2 Variable Metering Device Calculations

The Subcooling Charging Method is used only for systems equipped with variable metering devices. These include Thermostatic Expansion Valves (TXV) and Electronic Expansion Valves (EXV). Since variable metering devices are constant superheat valves, measuring the superheat determines whether they are working properly.

1. Calculate Actual Subcooling as the condenser saturation temperature minus the liquid line temperature. Actual Subcooling = $T_{condenser, sat} - T_{liquid}$.

2. Determine the Target Subcooling specified by the manufacturer.

3. Calculate the difference between actual subcooling and target subcooling (Actual Subcooling - Target Subcooling

4. In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer and the HERS Rater.

   For the Installer, If the difference is between minus 3°F and plus 3°F, then the system **passes** the required refrigerant charge criterion.

   For the HERS Rater inspecting the system, if the difference is between minus 4°F and plus 4°F, then the system **passes** the required refrigerant charge criterion

5. For the Installer, if the difference is greater than plus 3°F, then the system **does not pass** the required refrigerant charge criterion and the Installer shall remove refrigerant. Adjust refrigerant charge and

check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.

6. For the Installer, if the difference is between minus 3°F and minus 100°F, then the system **does not pass** the required refrigerant charge criterion, the Installer shall add refrigerant. Adjust refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.
7. Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature. Actual Superheat = $T_{suction,} - T_{evaporator, sat.}$
8. If possible, determine the Superheat Range specified by the manufacturer.
9. In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer and the HERS Rater.

   For the Installer, if the superheat is within the manufacturer's superheat range, then the system **passes** the metering device criterion. If the manufacturer's specification is not available and the superheat is between 4°F and 25°F, then the system **passes** the metering device criterion.

   For the HERS Rater inspecting the system, if the superheat is between 3°F and 26°F, then the system **passes** the metering device criterion.

RA3.2.2.7 Minimum Airflow

In order to have a valid charge test, the airflow shall be verified by passing the temperature split test. Alternatively, one of the three measurements in RA3.3 may be used with a measured airflow in excess of 300 cfm/ton. The temperature split test method is designed to provide an efficient check to see if airflow is above the required minimum for a valid refrigerant charge test. The following steps describe the calculations using the measurement procedure described in Section RA3.2.2.5. If a system fails, then remedial actions must be taken. If the airflow is changed and the refrigerant charge has previously been tested, then the refrigerant charge shall be re-tested. Be sure to run the air conditioner for 15 minutes after the final adjustments before taking any measurements. Both the airflow and charge must be re-tested until they simultaneously pass.

1. Calculate the Actual Temperature Split as the return air dry-bulb temperature minus the supply air dry-bulb temperature. Actual Temperature Split = $T_{return, db} - T_{supply, db}$
2. Determine the Target Temperature Split from Table RA3.2-3 using the return air wet-bulb temperature ($T_{return, wb}$) and return air dry-bulb temperature ($T_{return, db}$).
3. If a dash mark is read from Table RA3.2-3 then there probably was an error in the measurements because the conditions in this part of the table would be extremely unusual. If this happens, re-measure the temperatures. If re-measurement results in a dash mark, complete one of the alternate airflow measurements in Section RA3.3.
4. Calculate the difference between target and actual temperature split (Actual Temperature Split-Target Temperature Split).
5. In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer and the HERS Rater.

For the Installer,

a) If the difference is between plus 3°F and minus 3°F, then the system **passes** the adequate airflow criterion.

b) If the difference is greater than plus 3°F, then the system **does not pass** the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat the measurement procedure as often as necessary to establish adequate airflow. After the final adjustment, allow the system to stabilize for 15 minutes before taking the final measurements.

c) If the difference is between minus 3°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured in a manner that obtains the average temperature in the airflow.

d) If the re-measured difference is between plus 3°F and minus 3°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 3°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).

For the HERS Rater inspecting the system,

a) If the difference is between plus 4°F and minus 4°F, then the system **passes** the adequate airflow criterion.

b) If the difference is between minus 4°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured in a manner that obtains the average temperature in the airflow.

c) If the re-measured difference is between plus 4°F and minus 4°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 4°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).

RA3.2.3 Alternate Charge Measurement Procedure

This section specifies the alternate charge measurement procedure. Under this procedure, the required refrigerant charge is calculated using the *Weigh-In Charging Method*.

HVAC installers who must complete system installation verification when the outdoor temperature is below 55°F shall use this alternate procedure in conjunction with installing and charging the system in accordance with the manufacturer's specifications. HERS Raters shall not use this procedure to verify compliance. Split system air conditioners come from the factory already charged with the standard charge indicated on the nameplate. The manufacturer supplies the charge proper for the application based on their standard liquid line length. It is the responsibility of the HVAC installer to ensure that the charge is correct for each air conditioner and to adjust the charge based on liquid line lengths different from the manufacturer's standard.

Table RA3.2-2 Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F) ($T_{condenser, db}$)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																											
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23.0	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19.0	20.8	22.6	24.3	26.0	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15.0	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5.0	7.0	8.9	10.6	12.6	14.4	16.2	18.0	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10.0	12.0	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17.0	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5

Shaded area requires return plenum temperature of 70ºF or higher.

Table RA3.2-2 Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F) ($T_{condenser, db}$)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																												
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22.0	23.8	25.6	27.5	29.3	31.1
91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13.0	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.7
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10.0	12.0	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29.0
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24.0	26.0	28.0
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15.0	17.0	19.1	21.1	23.2	25.3	27.3
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27.0
103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14.0	16.1	18.2	20.3	22.4	24.5	26.7
104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11.0	13.1	15.2	17.4	19.5	21.7	23.8	26.0
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17.0	19.1	21.3	23.5	25.7
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10.0	12.2	14.4	16.6	18.7	21.0	23.2	25.4
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18.0	20.2	22.5	24.7
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4
111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	8.1	10.4	12.6	14.9	17.2	19.5	21.8	24.1
112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.6	9.9	12.2	14.5	16.8	19.1	21.5	23.8
113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	9.5	11.8	14.1	16.4	18.8	21.1	23.5
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	9.0	11.4	13.7	16.1	18.4	20.8	23.2
115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.6	10.9	13.3	15.7	18.1	20.5	22.9

Table RA3.2-3 Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry–Bulb (ºF) ($T_{return, db}$)	Return Air Wet-Bulb (ºF) ($T_{return, wb}$)																												
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8									
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5								
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1							
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7						
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2					
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7				
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1			
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5		
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

RA3.3 Field Verification and Diagnostic Testing of Forced Air System Fan Flow and Air Handler Fan Watt Draw

RA3.3 contains procedures for verifying airflow in split system and packaged air conditioning systems serving low-rise residential buildings. The procedure is also used to verify reduced fan watts achieved through improved air distribution design, including more efficient motors and air distribution systems with less resistance to airflow.

The refrigerant charge test described in Section RA3.2 requires verification of airflow sufficient for the refrigerant charge test. Table RA3.3-1 Summarizes the diagnostic measurement procedures in RA3.3 and shows their relationship to the equipment efficiency algorithms in RACM chapter 3.

Table RA3.3-1 – Summary of Diagnostic Measurements

Features that require verification	Variables and Equation Reference	Description	Standard Design Value	Proposed Design	
				Default Value	Procedure
Fan Watts	FanW/cfm RACM Eq. R3-20	The term FanW/cfm is the ratio of fan power in Watts to the cooling coil airflow.	FanW/cfm = 0.58	FanW/cfm = 0.80	RA3.3.3.3 Diagnostic Air Handler Watt Draw
Cooling Coil Airflow	FanCfm/ton RACM Eqs. R3-20	The term FanCfm/ton is the ratio of the *Cooling coil airflow* to the nominal cooling capacity in tons.	FanCfm/ton = 350	FanCfm/ton = 300	RA3.3.3.1 Diagnostic Fan Flow
Refrigerant Charge Prerequisite	n. a.	The unit must pass the temperature split test or an airflow of at least 300 cfm/ton must be obtained for a valid refrigerant charge test	n. a.	n. a.	RA3.2.2.7 Temperature Split Method or RA3.3.3 .1 Diagnostic Fan Flow

RA3.3.1 Instrumentation Specifications

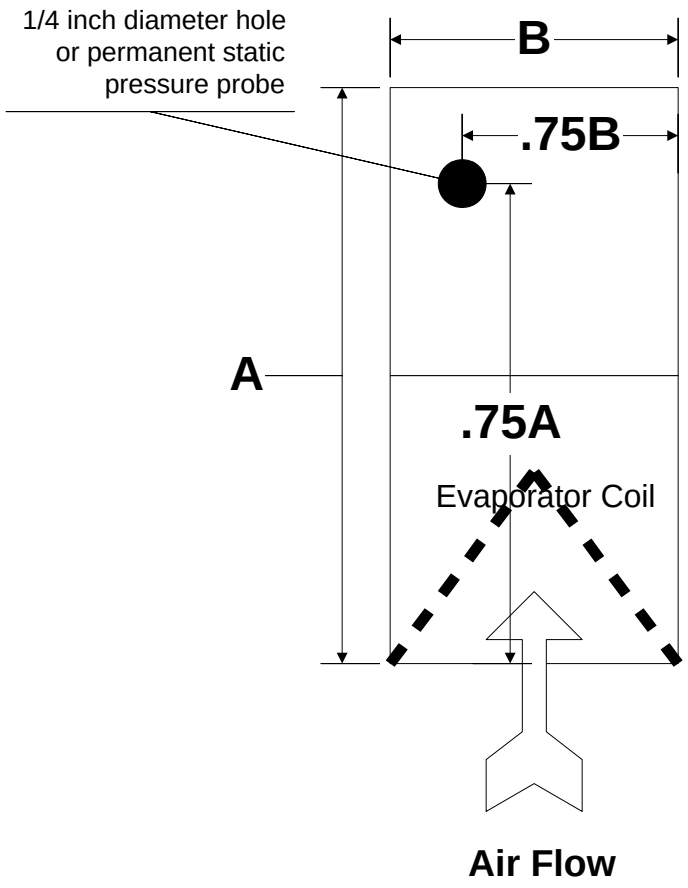
The instrumentation for the diagnostic measurements shall conform to the following specifications:

RA3.3.1.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of plus or minus

0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes Dwyer A303 or equivalent.

When supply plenum pressure measurements are used for plenum pressure matching or flow grid measurements, the supply plenum pressure shall be taken at the following location.



This location can be in any one of the four sides of the coil box/supply plenum.

This location shall have a 1/4" (6 mm) diameter hole (HSPP) or a permanently affixed static pressure probe (PSPP). The location shall be labeled "Title 24 – Supply Pressure Measurement Location" in at least 12-point type.

RA3.3.1.2 Fan Flow Measurements

All measurements of distribution fan flows shall be made with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 7% reading or ± 5 cfm whichever is greater.

RA3.3.1.3 Watt Measurements

All measurements of air handler watt draws shall be made with true power measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 2% reading or ± 10 watts whichever is greater.

RA3.3.2 Apparatus

RA3.3.2.1 System Fan Flows

HVAC system fan flow shall be measured using one of the following methods.

RA3.3.2.1.1 Plenum Pressure Matching Measurement

The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter) meeting the specifications in RA3.3.1, a static pressure transducer meeting the specifications in Section RA3.3.1, The measuring device shall be attached at the air handler blower compartment door, or alternatively at the inlet to a return from the conditioned space. The measuring device shall be attached at a point where all the fan airflow shall flow through it. When the air handler blower compartment door is used an air barrier must be placed between the return duct system and the air handler inlet(s). All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum at the location specified in Section RA3.3.1.1 so that it is not moved during this test.

RA3.3.2.1.2 Flow Capture Hood Measurement

A flow capture hood meeting the specifications in Section RA3.3.1 may be used to verify the fan flow at the return register(s) if the device has a capture area at least as large as the returns in all dimensions. All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).

RA3.3.2.1.3 Flow Grid Measurement

The apparatus for measuring the system fan flow shall consist of a flow measurement device (subsequently referred to as a fan flow grid) meeting the specifications in RA3.3.1 and a static pressure transducer meeting the specifications in Section RA3.3.1. The measuring device shall be attached at a point where all the fan airflow shall flow through the flow grid. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum at the location specified in Section RA3.3.1.1 so that it is not moved during this test.

RA3.3.2.2 Air Handler Watts

The air handler watt draw shall be measured using one of the following methods.

RA3.3.2.2.1 Portable Watt Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of a wattmeter meeting the specifications in RA3.3.1. The measuring device shall be attached to measure the air handler fan watt draw. All registers and blower access panel(s) shall be in their normal operating condition.

RA3.3.2.2.2 Utility Revenue Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of the utility revenue meter meeting the specifications in RA3.3.1 and a stopwatch measuring in seconds. All registers and blower access panel(s) shall be in their normal operating condition.

RA3.3.3 Procedure

This procedure determines the cooling coil airflow, fan Watts, and duct design compliance.

To determine and verify airflow and fan watt draw credit, in addition to verifying airflow, the air handler fan watt draw measurement shall show fan watts less than that claimed in compliance software calculations and shown on the CF-1R.

RA3.3.3.1 Diagnostic Fan Flow

For compliance calculations using verified prescriptive cooling coil airflow, or for compliance calculations using target values for verified cooling coil airflow that exceed prescriptive airflow, the installed system shall be diagnostically tested using one of the methods specified in this section.

For multi-zone systems the airflow must be measured for each and every operating mode of the system. This must be accomplished without bypasses from the supply ductwork to the return ductwork. Note: All airflows are for the fan set at the speed used for air conditioning.

The system passes the Diagnostic Fan Flow test if the measured cooling coil airflow is equal to or greater than the value claimed in compliance calculations and reported by the ACM on the CF-1R.

Diagnostic fan flows shall be converted to Fan Cfm/ton by dividing the measured fan flow (Qah) by the nominal tons of the air conditioner. The measured airflow shall be expressed in cubic feet per minute of standard air (standard air has a density of 0.075 lb/ft3). When the airflow measurement is made at altitudes significantly different from sea level or at temperatures significantly different from 70°F, the airflow indicated on the device gauge may differ from the standard CFM by as much as 15 percent. Corrections from indicated to standard CFM shall be made using the procedure specified by the flow measurement device manufacturer.

RA3.3.3.1.1 Diagnostic Fan Flow Using Plenum Pressure Matching

This fan flow measurement shall be performed using the following procedures:

1. If the fan flowmeter is to be connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.
2. With the system fan on at the maximum speed used in the installation (the cooling speed when air conditioning is present), measure the pressure difference (in Pa) between the supply plenum and the conditioned space (Psp). Psp is the target pressure to be maintained during the fan flow tests. Place the pressure probe in the Supply Pressure Measurement Location described in Section 3.3.1.1. Adjust the probe to achieve the highest pressure and then firmly attach the probe to ensure that it does not move during the fan flow test.
3. If the fan flowmeter is to be connected to the air handler at the access, block the return duct system from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.
4. Attach the fan flowmeter to the duct system at the air handler or alternatively at the inlet to the return from the conditioned space with the grille and filter removed.
5. Turn on the system fan and the fan flowmeter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches Psp.
6. Record the flow through the flowmeter (Qah, cfm) - this is the diagnostic fan flow. In some systems, system fan and fan flowmeter combinations may not be able to produce enough flow to reach Psp. In this case record the maximum flow (Qmax, cfm) and pressure (Pmax) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Qmax and Pmax) to operating condition at operating pressure (Psp).

Equation RA3.3-1 Air Handler Flow Qah = Qmax x (Psp/Pmax) ^0.5

RA3.3.3.1.2 Diagnostic Fan Flow Using Flow Grid Measurement

The fan flow measurement shall be performed using the following procedures:

1. With the system fan on at the maximum speed used in the installation (the cooling speed when air conditioning is present), measure the pressure difference (in Pascal) between the supply plenum and the conditioned space (Psp). Place the pressure probe in the Supply Pressure Measurement Location described in Section 3.3.1.1. Adjust the probe to achieve the highest pressure and then firmly attach the probe to ensure that it does not move during the fan flow test.
2. The flow grid shall be attached at a point where all the fan air flows through the flow grid.
3. Re-measure the system operating pressure with the flow grid in place.
4. Measure the airflow through the flow grid (Qgrid) and the test pressure (Ptest).
5. The following equation for air handler flow shall be used to correct flow through the flow grid and pressure (Qgrid and Ptest) to operating condition at operating pressure (Psp).

Equation RA3.3-2 Qah = Qmax x (Psp/Ptest) ^0.5

RA3.3.3.1.3 Diagnostic Fan Flow Using Flow Capture Hood

The fan flow measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the cooling speed and measure the fan flow at the return grille(s) with a calibrated flow capture hood to determine the total system return fan flow. The system fan flow (Qah, cfm) shall be the sum of the measured return flows.

RA3.3.3.2 - RESERVED

RA3.3.3.3 Diagnostic Air Handler Watt Draw

The system passes the Watt Draw test if the air handler watt draw is less than or equal to the value claimed in compliance calculations and reported by the ACM on the CF-1R.For multi-zone systems the measured air handler watt draw must be less than or equal to the value claimed in compliance calculations and reported by the compliance software on the CF-1R. This must be accomplished with all zones operating and without bypasses from the supply ductwork to the return ductwork.

The diagnostic air handler watt draw shall be measured using one of the following methods:

RA3.3.3.3.1 Diagnostic Air Handler Watt Draw Using Portable Watt Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and measure the fan watt draw (Wfan).

RA3.3.3.3.2 Diagnostic Air Handler Watt Draw Using Utility Revenue Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and turn off every circuit breaker except the one exclusively serving the air handler. Record the Kh factor on the revenue meter, count the number of full revolutions of the meter wheel over a period exceeding 90 seconds. Record the number of revolutions (Nrev) and time period (trev, seconds). Compute the air handler watt draw (Wfan) using the following formula:

Equation RA3.3-3 Air Handler Fan Watt Draw Wfan = (Kh x Nrev x 3600) / trev

Return all circuit breakers to their original positions.

RA3.4 Procedures for Verifying the Presence of a Charge Indicator Display or High Energy Efficiency Ratio Equipment

RA3.4.1 Purpose and Scope

The purpose of these procedures is to verify that residential space cooling systems and heat pumps have the required components to achieve the energy efficiency claimed in the compliance documents. The procedures only apply when a Charge Indicator Display (CID) is specified for split system equipment or an EER higher than the default is claimed. For dwelling units with multiple systems, the procedures shall be applied to each system separately.

The installer shall certify to the builder, building official and HERS rater that he/she has installed all the correct components.

The reference method algorithms adjust (improve) the efficiency of air conditioners and heat pumps when field verification indicates the specified components are installed. Table RA3.4-1 summarizes the algorithms that are affected.

Table RA3.4-1 – SUMMARY OF FIELD VERIFICATION

			Proposed Design	
Field Verification Check	Description	Standard Design Value	Default Value	Procedure
Presence of a CID	F_{CID} takes on a value of 0.96 when the system has a verified CID or has been diagnostically tested for the correct refrigerant charge. Otherwise, F_{CID} has a value of 0.90.	Split systems are assumed to have refrigerant charge testing or a CID, when required by Package D.	No CID or refrigerant charge testing.	Section RA3.4.2
Presence of a matched High Efficiency Compressor Unit, Evaporator Coil, Refrigerant Metering Device, and (where specified) Air Handling Unit and/or Time Delay Relay.	The EER is the Energy Efficiency Ratio at 95 F outdoors specified according to ARI procedures for the matched combination	Systems are assumed to have the default EER based on SEER,	Default EER	Sections RA3.4.3 and RA3.4.4

RA3.4.2 CID Verification Procedure

The procedure shall consist of visual verification that the CID is installed on the system.

RA3.4.3 Time Delay Relay Verification Procedure

When a high EER system specification includes a time delay relay, the installation of the time delay relay shall be verified.

The procedure shall be:

1) Turn the thermostat down until the compressor and indoor fan are both running.
2) Turn the thermostat up so the compressor stops running.
3) Verify that the indoor fan continues to run for at least 30 seconds.

RA3.4.4 Matched Equipment Procedure

When installation of specific matched equipment is necessary to achieve a high EER, installation of the specific equipment shall be verified.

The procedure shall consist of visual verification of installation of the following equipment and confirmation that the installed equipment matches the equipment required to achieve the high EER rating:

1) The specified labeled make and model number of the outdoor unit.
2) The specified labeled make and model number of the inside coil.
3) The specified labeled make and model of the furnace or air handler when a specific furnace or air handler is necessary to achieve the high EER rating,
4) The specified metering device when a specific refrigerant metering device (such as a TXV or an EXV) is necessary to achieve the high efficiency rating.

RA3.5 High Quality Insulation Installation Procedures

RA3.5.1 Purpose and Scope

RA3.5 is a procedure for verifying the quality of insulation installation in low-rise residential buildings. A compliance credit is offered when this procedure is followed by the insulation installer and a qualified HERS rater. The procedure and credit applies to wood framed construction with wall stud cavities, ceilings, and roof assemblies insulated with mineral fiber or cellulose insulation in low-rise residential buildings.

The procedure for verifying the quality of closed-cell spray polyurethane foam (SPF) insulation installation is outlined Joint Appendix JA7.

RA3.5.2 Terminology

Air Barrier	An air barrier is needed in all thermal envelope assemblies to prevent air movement. Insulation, other than foam, is not designed to stop air movement. For insulation installed horizontally, such as in an attic, the insulation must be in substantial contact with the assembly air barrier (usually the ceiling drywall) on one side for it to perform at its rated R-value. A wall or ceiling covering that has multiple leakage sites (such as 1 x 6 tongue and groove board ceilings) can not serve as an air barrier.
Air-tight	Thermal envelope assemblies (such as wall assemblies) shall be built to minimize air movement. Air movement can move unwanted heat and moisture through or into the assembly. For these procedures air-tight shall be defined as an assembly or air barrier with all openings greater than 1/8 inch caulked, or sealed with expansive or minimally expansive foam.
Excessive Compression	Batt insulation may be compressed up to 50 percent at obstructions such as plumbing vents and in non-standard cavities, but compression of more than 50 percent in any dimension is excessive and shall not be allowed. Where obstructions would cause the insulation to be compressed greater than 50 percent insulation shall be cut to fit around the obstruction.
Delaminated	Batts are often split or delaminated to fit around an obstruction. For example when an electrical wire runs through a wall cavity the insulation must still fill the area both in front of the wire and the area behind the wire. This is typically accomplished by delaminating the batt from one end and placing one side of the batt behind the wire and the other in front of the wire. The location of the delamination must coincide with the location of the obstruction. For example if the wire is one third of the distance from the front of the cavity the batt should be delaminated so that two thirds of the batt goes behind the wire and one third in front of the wire.
Draft Stops	Draft stops are installed to prevent air movement between wall cavities, other interstitial cavities - and the attic. They are typically constructed of dimensional lumber blocking, drywall or plywood. Draft stops become part of the attic air barrier and shall be air-tight. Fire blocks constructed of porous insulation materials cannot serve as draft stops since they are not air-tight.
Friction Fit	Friction fit batts are commonly used. Friction fit batts have enough side-to-side frictional force to hold the batt in place without any other means of attachment.
Gaps	A gap is an uninsulated area at the edge of or between batts. Gaps in insulation are avoidable and are not permitted.
Hard Covers	Hard covers shall be installed above areas where there is a drop ceiling. For example a home with 10 ft ceilings may have an entry closet with a ceiling lowered to 8 ft. A hard

cover (usually a piece of plywood) is installed at the 10 ft. level above the entry closet. Hard covers become part of the ceiling air barrier and shall be air-tight.

Inset Stapling — In windy areas installers often staple the flanges of faced batts to the sides of the stud in order to assure that the insulation remains in place until covered with drywall, particularly on the wall between the house and the garage where there isn't any exterior sheathing to help keep the insulation in place. The void created by the flange inset shall not extend more than two inches from the stud on each side.

Net Free-Area — The net free-area of a vent cover is equal to the total vent opening less the interference to air flow caused by the screen or louver. Screened or louvered vent opening covers are typically marked by the manufacturer with the "net free-area." For example a 22.5 in. by 3.5 in. eave vent screen with a total area of 78.75 square inches may have a net free-area of only 45 square inches.

Voids — When batt insulation is pushed too far into a wall stud cavity a void is created between the front of the batt and the drywall. Batts shall be fully lofted and fill the cavity front-to-back. Small voids less than ¾ in. deep on the front or back of a batt shall be allowed as long as the total void area is not over 10 percent of the batt surface area. This definition shall not preclude the practice of inset stapling as long as the void created by the flange inset meets the specification in the definition of inset stapling. Improper spraying or blowing of insulation in ceilings and wall cavities can result in areas with insufficient insulation not meeting the specified installed density and R-value. Wall and cathedral ceiling cavity areas where cellulose insulation has fallen away shall be filled with insulation. Depressions in netting or material supporting blown insulation in walls and cathedral ceilings shall be filled with insulation.

RA3.5.3 Raised Floors and Floors Over Garages

- Batts shall be correctly sized to fit snugly at the sides and ends, but not be so large as to buckle.
- Batts shall be cut to fit properly without gaps. Insulation shall not be doubled-over or compressed.
- Insulation shall be in contact with an air barrier - usually the subfloor.
- On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- If the insulation is faced, the facing shall be placed toward the living space and be in contact with the underside of the floor sheathing. Continuous support shall be provided to keep the facing in contact with the floor sheathing. Filling the entire cavity with insulation and providing support with netting at the bottom of the framing is one acceptable method.
- Insulation shall be properly supported to avoid gaps, voids, and compression.

RA3.5.4 Wall Insulation

RA3.5.4.1 Batt Installation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate. All gaps in the air barrier greater then 1/8 inch shall be caulked, or sealed with expansive or minimally expansive foam.
- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.

- The batt shall be friction fitted into the cavity unless another support method is used.
- Batt insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Batts with flanges that are inset stapled to the side of the stud must be flush with the face of the cavity (or protrude beyond) except for the portion that is less than two inches from the edge of the stud.
- Non-standard-width cavities shall be filled with insulation fitted into the space without excessive compression.
- Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.

RA3.5.4.2 Narrow-Framed Cavities

- Non-standard width cavities ¼ inch or wider shall be filled by batt insulation cut to snuggly fit into the space or filled with loose fill insulation or expanding foam.
- Narrow spaces (two inches or less) at windows, between studs at the building's corners, and at the intersections of partition walls shall be filled with batt insulation snuggly fitted into the space (without excessive compression), loose fill insulation, or expansive or minimally expansive foam.

RA3.5.4.3 Special Situations

RA3.5.4.3.1 Installations Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities such as;0 corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. Special care shall be taken to insure the above cavities are air tight. This may have to be done prior to the installation of the exterior sheathing or the stucco lath.

RA3.5.4.3.2 Obstructions

- Insulation shall be cut to fit around wiring and plumbing without compression.
- Insulation shall be placed between the sheathing and the rear of electrical boxes and phone boxes.
- In cold climates, where water pipes may freeze (Climate Zones 14 and 16) pipes shall have at least 2/3 of the insulation between the water pipe and the outside. If the pipe is near the outside, as much insulation as possible shall be placed between the pipe and the outside (without excessive compression), and no insulation shall be placed between the pipe and the inside.

RA3.5.4.3.3 Rim Joists

- All rim-joists shall be insulated to the same R-Value as the adjacent walls.
- The insulation shall be installed without gaps or excessive compression.

RA3.5.4.3.4 Kneewalls and Skylight Shafts

- All kneewalls and skylight shafts shall be insulated to a minimum of R-19.
- The insulation shall be installed without gaps and with minimal compression.
- For steel-framed kneewalls and skylight shafts, external surfaces of steel studs shall be covered with batts or rigid foam unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- The insulation shall be supported so that it will not fall down by either fitting to the framing, stapling in place with minimal compression, or using other support such as netting.

RA3.5.4.3.5 HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to the same R-value as the exterior walls.

RA3.5.4.3.6 Loose Fill Wall Insulation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate. All gaps in the air barrier greater then 1/8 inch shall be caulked, or sealed with expansive or minimally expansive foam.
- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- Loose fill insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Loose fill wall insulation shall be installed to fit around wiring, plumbing, and other obstructions.
- The installer shall certify on the Installation Certificate forms that the manufacturer's minimum weight-per-square-foot requirement has been met.

RA3.5.5 Ceiling and Roof Insulation

RA3.5.5.1 Batt Insulation

RA3.5.5.1.1 General Requirements

- Batts shall be correctly sized to fit snugly at the sides and ends.
- Batts shall be installed so that they will be in contact with the air barrier.
- Where necessary, batts shall be cut to fit properly - there shall be no gaps, nor shall the insulation be doubled-over or compressed.
- When batts are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity without excessive compression.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- For batts that are taller than the trusses, full-width batts shall be used so that they expand to touch each other over the trusses.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the batt.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RA3.5.5.1.2 Special Situations

RA3.5.5.1.2.1 Rafter Ceilings

- An air space shall be maintained between the insulation and roof sheathing if required by California Building Code section 1203.2.

- Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RA3.5.5.1.2.2 HVAC Platform

- Appropriate batt insulation shall be placed below any plywood platform or cat-walks for HVAC equipment installation and access.
- Batts shall be installed so that they will be in contact with the air barrier.

RA3.5.5.1.2.3 Attic Access

- Permanently attach rigid foam or batt insulation with the appropriate R-value to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be gasketed to prevent air movement.

RA3.5.5.2 Loose-Fill Ceiling Insulation

RA3.5.5.2.1.1 General Requirements

- Baffles shall be placed at eaves or soffit vents to keep insulation from blocking eave ventilation. The required net free-ventilation shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the loose-fill insulation
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed or the entire drop area shall be filled with loose-fill insulation level with the rest of the attic.
- Attic rulers appropriate to the material installed shall be evenly distributed throughout the attic to verify depth: one ruler for every 250 square feet and clearly readable from the attic access. The rulers shall be scaled to read inches of insulation and the R-value installed.
- Insulation shall be applied underneath and on both sides of obstructions such as cross-bracing and wiring.
- Insulation shall be applied all the way to the outer edge of the wall top plate.
- Insulation shall cover recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturer's installation instructions or labels on the flue.
- Insulation shall be blown to a uniform thickness throughout the attic with all areas meeting or exceeding the insulation manufacturer's minimum requirements for depth and weight-per-square-foot.
- The installer shall certify on the Installation Certificate forms that the manufacturer's minimum weight-per-square-foot requirement has been met.
- The HERS rater shall verify that the manufacturer's minimum weight-per-square-foot requirement has been met for attics insulated with loose-fill mineral-fiber insulation. Verification shall be determined using the methods of the Insulation Contractor's Association of America (ICAA) Technical Bulletin #17 except that only one sample shall be taken in the area that appears to have the least amount of insulation. The rater shall record the weight-per-square-foot of the sample on the Certificate of Field Verification and Diagnostic Testing (CF-6R).
- The HERS rater shall verify that the manufacturer's minimum insulation thickness has been installed. For cellulose insulation this verification shall take into account the time that has elapsed since the insulation was installed. At the time of installation, the insulation shall be greater than or equal to the

manufacturer's minimum initial insulation thickness. If the HERS rater does not verify the insulation thickness at the time of installation, and if the insulation has been in place less than seven days, the insulation thickness shall be greater than the manufacturer's minimum required thickness at the time of installation less 1/2 inch to account for settling. If the insulation has been in place for seven days or longer, the insulation thickness shall be greater than or equal to the manufacturer's minimum required settled thickness.

RA3.5.5.2.2 Special Situations

RA3.5.5.2.2.1 Kneewalls and Skylight Shafts:

- Kneewalls and skylight shafts shall be insulated to a minimum of R-19. If loose fill insulation is used it shall be properly supported with netting or other support material.

RA3.5.5.2.2.2 HVAC Platform

- Pressure-fill the areas under any plywood platform or walks for HVAC equipment installation and access or verify that appropriate batt insulation has been installed.

RA3.5.5.2.2.3 Attic Access

- Permanently attach rigid foam or a batt of insulation to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be properly gasketed to prevent air movement.

RA3.5.6 Materials

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Chapter 26 and Section 706 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.

RA3.5.7 Equipment

- Scales - The scales used to weigh density samples shall be accurate to within plus or minus 0.03 pounds and calibrated annually.

RA3.5.8 R-Value and U-Value Specifications

See the Certificate for Compliance (CF-1R) for minimum R-value requirements; Refer to Reference Joint Appendix JA4 for construction assemblies.

RA3.5.9 Certificates

An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value, and, in applications of loose-fill insulation, the minimum installed

weight-per-square-foot (or the minimum weight per cubic foot) consistent with the manufacturer's labeled installed-design-density for the desired R-Value, and the number of inches required to achieve the desired R-Value. The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a bag label or a manufacturer's coverage chart for every insulation material used.

RA3.5.10 Certificate Availability

The Insulation Installation Certificate (CF-6R), with insulation material bag labels or coverage charts attached), signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

RA3.6 Field Verification and Diagnostic Testing of Photovoltaic Systems

RA3.6.1 Purpose and Scope

The field verification and diagnostic testing procedures in this Appendix are intended to ensure that the:

- PV modules and inverters used in the expected performance calculations are actually installed at the applicable site;
- PV modules are minimally shaded, or if shaded, that the actual shading does not exceed the shading characteristics were included in the expected performance calculations; and
- Measured output power from the system matches that expected by the PV Calculator within the specified margin at the prevailing conditions at the time of field verification and diagnostic testing.

This is required to comply with the NSHP Compliance Option as explained in the Residential ACM Manual Appendix B. The actual protocol is included in Appendix 4 of the New Solar Homes Partnership Guidebook (most current version, available at http://www.gosolarcalifornia.ca.gov/documents/index.html).